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Rockville, Maryland

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*THE IMPORTANCE OF CONTROLLED TIPPING**

By Dipl. Ing. K. Wuhrmann, EAWAG, Zurich

Controlled tipping is a well defined procedure with predictable consequences, not to be confused with the garbage piling practiced until recently, which consisted solely in dumping the waste on empty plots, with the permission of the landlords.

Controlled deposition aims at removing all unwanted material, avoiding, at the same time, any undesirable effects on the environment and on living space in general. This infers:

a) no smoke
b) no perceptible odor beyond the depositing site
c) no drifts
d) no unaesthetic sights
e) no marked effect on groundwater or surface water
f) no vermin
g) no unreasonable noise.

1. Why controlled tipping?

Man's demands on his surroundings increase with the progressive refinement of the standard of living in highly civilized communities, when the struggle for existence is replaced by other worries, real or imagined, but in any case less essential ones (the problems of the welfare state). Controlled tipping is now often flatly rejected because of the ill-fame that attaches to the well known haphazard garbage piling.

Nevertheless, no modern community can manage without garbage tips. The question is only how and where to tip. The smaller the reduction in volume through sorting, collecting and transportation, and pretreatment by incineration and composting, the higher are the transportation costs and the shorter is the distance that can be covered at reasonable cost from the area of origin to the tipping site. The provisions for controlled tipping are, however, closely correlated with the topography, and a small area offers, in all probability, fewer facilities than a large area. In addition, the cost of controlled tipping depends upon the type of refuse so that the economic aspect of processing (incineration or composting) must also be investigated.

* See "Der Städtetag", No. 6, 1957

2. Types of controlled tipping

The designation "controlled tipping" does not indicate what is tipped. Therefore, it should be decided in every case what is to be tipped. The following types are distinguished:

a) General tipping:
Refuse, such as domestic garbage, bulky waste material, industrial waste (excepting poisonous residues), slag and ash, rubble, dry sewage sludge, etc.

b) Coarse material:
Bulky waste material, inert industrial wastes, slag and ash, also rubble

c) Ash:
Fuel wastes only

d) Rubble:
Only excavated material and remains of ruined buildings, free of any significant quantity of organic material

e) Industrial wastes:
Only noncombustible and nonpoisonous wastes

Disposal of wastes b to e may be combined if necessary. In addition, there is a whole range of other specific wastes, such as soil washouts, mining rubble, radioactive wastes, carbide sludge etc., which will not be discussed in detail here. Disposal of poisonous material is the subject of several controversial theories.

3. Planning

In order to prove satisfactory from every angle, tips should be carefully planned. Investment costs as well as running expenses depend chiefly upon the nature of terrain. It is therefore advisable to examine first the imponderables connected with the selection of the site.

a) Water conservation

Basically, a tip is exposed to leaching by precipitations, surface water or groundwater. Given the extent of the tipping area, the inflow of water cannot be prevented with absolute certainty. On the other hand, water inflow can be kept within narrow limits so that very little, or no effluent water at all would have to be taken into account. However, if a water outlet is unavoidable there are various criteria and appropriate precautionary measures to be considered:

aa) leaching is harmless (rubble, gravel, inert material);

bb) the eluate flows into surface- or groundwater courses which are already so heavily contaminated that any additional load is negligible;

cc) the eluate can be caught on the spot and adequately purified, or canalized and channelled to an existing purification plant without impairing the efficiency of the latter (valid particularly for decomposable organic matter);

dd) the eluate is collected and periodically channelled to a processing plant.

Periodic drainage of runoff and seepage water is an expedient means of keeping the amount of eluate, and hence the expenses, within reasonable limits. In any case, contact with flowing or stagnant waters should be avoided whenever possible. The old custom of filling in gullies and ravines mostly leads to expensive solutions right from the start, because of the streams that flow in them. Slopes, round hilltops and ridges are preferable, but there are disadvantages from the aesthetic point of view.

As regards precipitation waters, the local amount of precipitation and the extent of evaporation, which is dependent on the type of tip, are important. Losses by evaporation in Germany amount, on the average, to 30 – 50% per year. According

to the materials tipped the absorption properties of the tip itself should be taken into account. Harmful leachings usually consist of dissolved substances, especially carbonates, chlorides and sulfates, as well as carbon dioxide. The salts can be removed from the water by various means, first and foremost by ion-exchangers. In certain conditions, natural factors such as vegetation cover and humus may also contribute to this end.

b) **Air hygiene**

Drifts and odors as well as smoke can be prevented by controlled tipping. As long as the necessary cover material is available air hygiene hardly affects selection of the site. Nevertheless, areas exposed to winds should be avoided, or used only after planting suitable shelter belts, especially if the refuse consists mainly of light dusts and sweepings.

c) **Vermin**

In accordance with accepted viewpoints, it may be demanded that the tip do not shelter or become a breeding ground for animals that would otherwise be found in the neighborhood in small numbers only, or not at all.

The most prominent inhabitants of haphazard dumps are rats, mews and crows. As far as possible these animals and birds should be kept away, and this is feasible by controlled tipping. Rats are eliminated by continuous compacting of the material throughout the tip. Therefore, the thickness of the layers is limited. Since rats are known to be dangerous disease carriers, rat-control measures are advisable, though unnecessary if compacting is properly carried out.

Birds settle on dumps only if edible wastes are found on the surface within a certain distance from the tipping site.

If the tip is thoroughly covered so that only the site on which the tractors are at work is exposed, then mews, crows etc., are not attracted.

The same is true for insects. Another question arises in connection with tips occasionally containing fermentable substances, especially incompletely burned fuel remnants, or mixed tippings of ash and fresh refuse. In principle, this type of tipping can be carried out without compacting or covering, provided the fermentable and convertible refuse does not exceed a proportionally small fraction. However, insects, particularly flies may occur in certain atmospheric conditions. Although hardly any objections have been raised, so far the possible consequences should not be overlooked.

d) **Aesthetics**

This is one of the most important aspects to be considered in connection with tips. It was ignored in the past and continues to be ignored at present; this is the reason for the resistance encountered to controlled tipping. From this aspect careful selection of the tipping site is of the utmost importance. For the sake of landscape protection only hidden depressions or troughs should be chosen, so that they remain entirely invisible, or can be seen only from a certain distance. Owing to the continuous covering with soil-colored or sandy excavations, the controlled tipping areas do not appear variegated, but look rather like arable land, or some small building site. Cases are known where tipping of slag and domestic refuse proceeded in residential areas amid well-kept houses without arousing any objections. The drifts in connection with tipping have been discussed above in the section dealing with air hygiene.

Almost as important as the tidy aspect of the actual tipping site is the tidiness of the immediate vicinity. In order to achieve this, a certain amount of educational work is required. People should learn not to discard the refuse at any time, anywhere on the road leading to the tip. In general, it is advisable to fence-in the tipping area and open the gate only when the caretaker is present. In order to keep the area clean the authorities concerned should carry out intensive campaigns of enlightenment, and indicate precisely the hours during

which the tipping site is open, thus facilitating tipping within the framework of controlled tipping by those who could not, for some reasons, take advantage of the regular refuse-collection times. For small loads, acceptance free of charge is advisable.

However, if disorderly dumping occurs the police should be called in. More often than not the culprit can be identified by the items discarded.

Orderly controlled tipping requires clean access roads to the tip. Surfaced roads are preferable. In order to keep the roads clean even in bad weather either anchored tipping places should be provided within the tipping site, or the tires of outgoing vehicles should be properly cleaned at special washing places.

Cleaning facilities should be provided also for the personnel and implements. For this purpose a small room should be made available with the necessary equipment for washing and storage of implements. Running water is, therefore, desirable, as well as spray under pressure for cleaning the vehicles.

4. Mode of operation

Two kinds of tips are distinguished: those that must be covered, and tips that need not be covered. In the latter, the tipped material is in itself a cover. Among the former tips, some are covered with material brought from outside, such as material from building sites, refuse-ash, etc., which may be available in sufficient quantities; or the material may have to be specially excavated elsewhere for this purpose. These tips should always have covering material in store in case regular transports are interrupted, for instance, by severe frosts. Another way of providing covering material is by excavating on the tipping site itself. The method of operation in this case depends on the topography of the place selected.

Investment in special equipment for internal transportation of the refuse, and the leveling and compacting thereof is advisable in large tipping areas. As regards domestic waste, the small bulk weight should be taken into account. This fact has induced many municipalities in the U.S.A. to use cross-country vehicles with a load capacity exceeding 100 m^3. Scrapers are used for leveling, whereas compacting is carried out with caterpillar tracks as well as with spike-tooth rollers, or with pneumatic compactors fitted with toothed wheels. Exceptionally compact tips can be achieved with the aid of such equipment.

Examples of various tips are described below. First of all, these are tips that require compacting and covering; the technique of horizontal compacting is suitable for flat ground as well as for slopes (Figure 1).

Tipping of the first layer begins as soon as the approach to the tip is ready and the installation completed in accordance with the water-protection requirements. Better dewatering of the driveway is achieved by maintaining a slight incline, even if the covering material is not readily dewatered. If the tipping leads to the formation of a slope, as in the case illustrated, a protective rim of covering material should be built in good time, so that certain objects, such as tires, barrels, etc. are prevented from rolling off the dump and giving the site an untidy appearance.

Compacting proceeds mostly in tiers from an easily accessible tipping point, at the same time as the deposited material is spread.

Conflicting opinions exist in regard to the use of the discharging vehicles for the purpose of compacting. A loaded truck certainly adds more to compacting the surface than a caterpillar truck. Unlike the caterpillar, however, the tires do not level the driveway in the case of heterogeneous material; moreover, owing to more effective compacting, the rainwater collects in pools on the surface. This leads to sludging and soiling of the vehicles, and in summer to excessive dust.

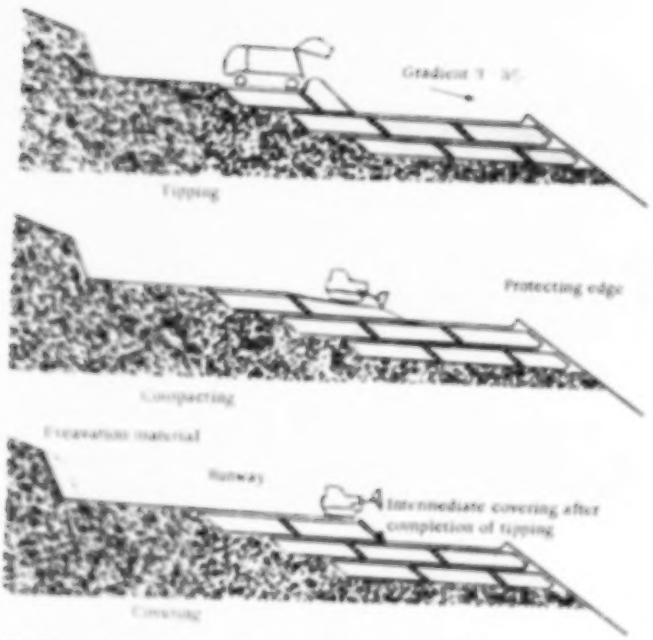

FIGURE 1. The three phases of deposition in slightly inclined layers (e.g. on slopes)

In any case, the increased demand upon the vehicles and their wear and tear, as well as the frequent soiling reduce the possible saving of tractor-hours. If it is intended that the refuse hauling vehicles should reach the actual tipping site, then the access track must be leveled out from time to time.

At the end of a day's tipping covering material is excavated by tractors, or brought from the stored deposits, the track completed and the shoulder protected by an intermediate cover. When the day's work is completed no garbage is left around. Drifts, fires and odors are thus effectively prevented. With rational planning excavation of the covering material can be so scheduled as to prepare simultaneously the approach road and the position for the next layer.

The technique of compacting in the case of inclined layers is applied primarily on level or gently sloping ground (*Figure 2*). In principle, the refuse is tipped on the same spot for a considerable time, but the tractor is generally driven farther. Therefore, if this technique is adopted it is advisable to surface the entire access road including the tipping site, and thus avoid soiling of wheels and cleaning of the vehicles in bad weather.

This procedure is particularly suitable for raising the height of the terrain gradually (in which case the approach road is slightly raised towards the tipping trough). It is also distinguished by excellent compacting, since on the way up the load is simultaneously crushed and pressed. This effect is achieved at the price of greater power of the tractors; on the other hand, the lower maintenance costs of the transport vehicles should be taken into account.

Both procedures described above can be combined with a chute (*Figure 3*), which is most suitable whenever the approach road is higher than the tipping spot, and when the quantity to be deposited does not justify the building of a paved ramp and washing place. If the criteria indicated above are to be met, certain measures against drifts will have to be taken. These consist mainly in providing suitable screens against the wind at the tipping site.

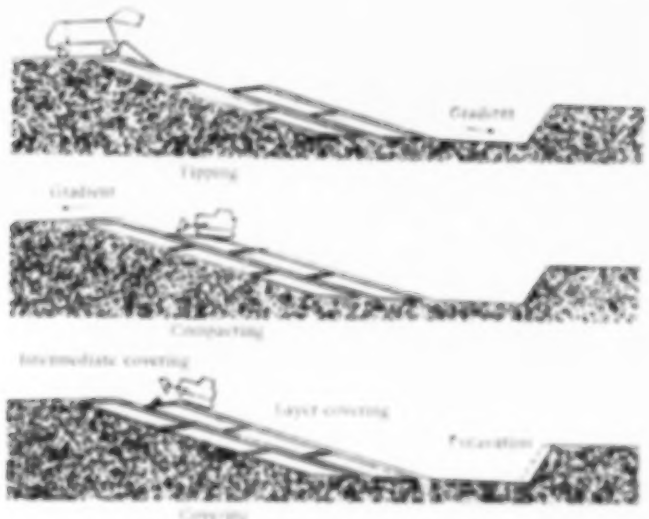

FIGURE 5. The three phases of deposition in thinly tipping layers (e.g. in plains)

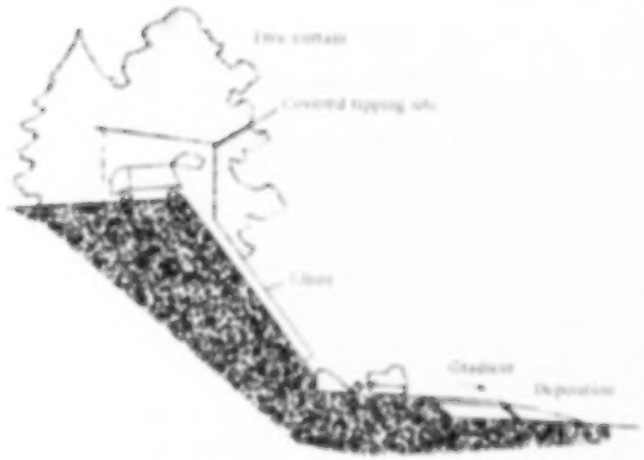

FIGURE 6. Deposit with local tipping site and crane

In plains, the possibility of drifts throughout the operations should be borne in mind. In certain conditions it is advisable to erect walls from the excavated earth, or fences of wire netting that will enclose the entire plot at the same time. Plantations are most desirable, also from the aesthetic aspect.

If covering material cannot be obtained on the spot as happens, for instance, in rocky ground, a supply of rubble or garbage for covering should be provided. Not all excavated material is suitable for covering. Clayey soils are not suitable since their handling is particularly difficult in wet weather.

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Neither are sludges suitable for this purpose. On the other hand, slag and especially gravel can be very well used. If the hydrogeological conditions of the tip necessitate prevention of contact with precipitations, an impermeable layer should be inserted in the covering. This procedure is justified provided it is expertly carried out, so that the inevitable accumulations do not cause leakages or trough formations. This technique is most effective if applied on top of the usual covering, while a high gradient is maintained. Mechanical compaction or ponding the fill is imperative. The cost involved warrants application of this procedure only in exceptional cases.

5. The tip in the landscape

The chemical and physical processes occurring in tips have been analyzed with particular attention to fresh refuse deposits. However, present knowledge in this field is far from complete, and no precise information can yet be given about all the various aspects.

The types of alkalization have already been mentioned. Concerning the organic matter, it should be borne in mind that with increasing depth the access of oxygen diminishes. As long as water has access, a slow, anaerobic process sets in which may last several years. The subsequently occurring products of degradation do not reach a significant concentration, and hence groundwater pollution appears only where the dump is in close contact with the groundwater. Since degradation becomes weaker with increasing depth, the rate of settling decreases steadily from top to bottom. In controlled tipping it is altogether low, in contrast to the dumpings practiced until recently, which were interspersed with numerous hollow spaces.

6. Costs

No refuse disposal complying with present-day requirements is cost-free. In controlled tipping the following expenses arise:

A. **Capital expenditure**
A 1. Land acquisition (alternative see B 5)
A 2. Approach road (newly built or reinforced)
A 3. Service room and tractor garage
A 4. Piping and wiring
A 5. Canalization, drainage, waste-water clarification
A 6. Protection against winds, plantations, fencing
A 7. Tire washing place, or tipping place with chute
A 8. Caterpillar tractors (alternative see B 6)

B. **Running expenses**
B 1. Salaries, wages, and social service contributions
B 2. Operation expenses (Diesel oil, grease, tools, cleaning material)
B 3. Maintenance of vehicles and buildings
B 4. Administration and insurance
B 5. Lease or tipping charges (alternative see A 1)
B 6. Tractor hire charge (alternative see A 8).

In general, it pays to buy the dumping plot, since it can always be sold at least at the same price at which it was bought. In connection with this item of expenditure, extraordinary differences are encountered at times, according to the topography and density of habitation.

This can be elucidated by a calculation example:

For a yearly quantity of 8,000 tons requiring approximately an equal number of cubic meters in deposition volume, with covering material excavated on the spot, 2 ha of land can be bought outside the building area at DM 10/m², i.e., for DM 200,000.

If this plot is resold after completion of tipping for, at least, the same price, the yearly capital expenditure at 6% interest amounts to DM 12,000. Assuming that 80% of the plot can be covered with an average of 5 m, its effective volume will be 80,000 m³, and thus sufficient for 10 years. The specific cost of the plot thus amounts to DM 1.5/t.

The costs of an adequate approach road are, at times, very high. Assuming that these will amount to DM 50,000, and that the road will be useless in the subsequent development of the area (which is highly improbable), the amortization of the road apart from interest must be taken into account, which in the given case amounts to DM 0.9/t.

Not less expensive, though varying in each case, are canalization, piping and wiring, drainage, and possible purification plants. From this aspect, the choice of a suitable terrain is decisive. Accordingly, the specific expenses may fluctuate from 0 to several marks per ton.

The service room, garage and washing place may be of lightweight construction, which together with piping and wiring would not exceed DM 20,000. To these should be added the costs of fencing and plantation, which easily require an additional DM 20,000. The capital investment for these will be about DM 0.7/t.

Since the tractor required should be suitable for heavy work, as already mentioned, its purchase price would be approximately DM 10,000. For a life span of 6 years (9,600 work hours) the capital required will be DM 20,500, or DM 2.5/ton.

A tip of this size can be run by one man only (without a fire-washing installation), provided the man is a skilled tractor-driver and has the necessary understanding for the hygienic and aesthetic requirements of tipping; he should also be able to attend to the maintenance of the equipment and installations. Including social service contributions and gratuities, the amount of approximately DM 15,000/yr, or DM 1.9/t, should be taken into account.

The working time of the tractor fluctuates, according to the method of tipping, between 0.15 and 0.25 h/t. On the average, we may assume that 1,600 h/yr are required. Maintenance and running expenses would amount to DM 16/h, and together with the cost of a stand-by tractor (in the case of repairs) they may be estimated at approximately DM 3.5/t.

Maintenance of the buildings and management expenses may be estimated at DM 8,000/yr, or DM 1/t.

Hence, for a plot of 8,000 t/yr the following costs result:

A.	**Capital expenditure**	
	Terrain	DM 1.5/t
	Approach road	DM 0.9/t
	Dewatering (assumed)	DM 1.0/t
	Other constructions	DM 0.7/t
	Tractor	DM 1.9/t
		DM 6.0/t
B.	**Running expenses**	
	Personnel	DM 1.9/t
	Tractor	DM 3.5/t
	Constructions and management	DM 1.0/t
	Tire washing (if provided)	1.0/t
		DM 7.4/t
A + B	Total	DM 13.4/t

According to the data from the U.S.A., the costs involved for tips ranging from 20,000 to 200,000 t/yr are estimated at DM 13 to 9/t.

This example was intentionally calculated on the basis of rather unfavorable conditions. In many cases no such figures as those mentioned for the purchase of the terrain and the approach road, or for dewatering, need be taken into account, especially if the period of utilization can be prolonged. These expenses depend mainly upon the size of the installation and the average height of the tip. Thus, for example, if instead of the assumed 5 m, a height of 10 m can be achieved, the basic costs are cut by half in the first approximation.

Here, too, the number of inhabitants determines the running expenses. If, in the given example, only half the quantity of 8,000 t/yr were deposited, the period of utilization would double. This, however, would not reduce the specific capital expenditure but would raise the running expenses very considerably, since any definite savings can be made only on maintenance and operation.

ENERGY EXPENDITURE IN THE PASTEURIZATION OF SLUDGE

By Dipl. Ing. K. Wuhrmann, EAWAG, Zurich

1. Premises

From the annual averages of the costs involved in sludge disposal it was found that the most economical method consists in disposing the wet, not dewatered sludge directly in the fields (1). However, certain hygienic considerations prevent the disposal of sludge during the vegetation period in regions consisting mainly of pastures. At one of the EAWAG symposia, early in 1967, in Zurich, the hygienic aspects of dispcsal of sludge and liquid manure on green land were discussed (2).

The present study is based on the assumption that the sludge disposed in the feeding areas of cattle should be made harmless, notwithstanding the rather surprising fact that hygienists are divided in their opinions as to the infection hazard that sewage sludge may represent to the milk or meat consumers. We are not discussing here whether compulsory pasteurization of milk and meat products would not prove much more effective in combating infection from other sources and whether, in addition to providing greater protection for the consumer, it would not be more economical than pasteurization of the considerably larger quantities of sewage sludge.

Owners of purification plants in areas in which the agricultural use of the land serves mainly the dairy industry are faced with the following problems of sludge disposal:

1. Is there enough arable land available during the vegetation period to permit disposal of the digested sludge produced? If not:
2. Is it worth storing the surplus sludge until fall (approximately until the beginning of October)?
   a) in the purification plant
   b) in the subsidized tanks of associated contractors; if not:
3. What part of the yearly production should be pasteurized?
4. Would another kind of sludge disposal be more advantageous?

We shall deal only with the conditions arising in a case as stated in question 3. According to the data supplied by the Niersverband (2, page 157), in the local

conditions (sandy soil, primarily dairy industry) 50% of the yearly intake should be pasteurized. For a more accurate cost estimate it is important to establish the percentage in each individual case.

Knowledge of the hygienic requirements of the pasteurization process is one of the prerequisites for its interpretation. Actually, hygienists do not demand sterilization, but only pasteurization that will inhibit further multiplication of salmonellas and parasites. The data on the minimum temperature and duration vary even for ideal liquids. This is, however, of secondary importance, since the digested sludge may lead to clumping, which delays the formation of a homogeneous temperature field. On the other hand, routine bacteriological control of the basic sludge would involve rather unreasonably high expenses. Therefore, the simplest solution is to decide upon a temperature and duration that will guarantee safety from all aspects.

At present, a temperature of 70°C for 20 minutes is considered safe. Even if some particles are subjected only to 65°for 10 min, owing to certain factors (e.g., beginning of operation, temperature fluctuations of a regulatory nature, etc.), they will still be pasteurized.

Of course, the processed sludge must not be contaminated by the incoming material. Hence, all heating techniques implying direct wetting of heat-exchangers (such as oil, as an intermediate heat carrier) should be excluded. For the sake of economy, hermetic heat exchangers and recuperation procedures with artificially lowered boiling points may be introduced.

2. Energy requirements

The cost of pasteurization must be calculated if it is to be compared with other disposal methods. Since the sludge portion (see part 1) to be pasteurized must be heated to 70°C, the cost of heat production per year plays an important role. Comparative costing calculations have already been made for pasteurization of fresh and digested sludge (2). However, these calculations cannot encompass the imponderables of fresh-sludge processing (possibly increased emanation of odors, reduction in volume through digestion and simultaneous increase in the work by the digestion water); it would appear that extensive investigation of the digestion-tank operation is still lacking as far as procedure and economy are concerned. Further, since at present only a few purification works, completely equipped yet not working on the principle of digestion, possess sufficient experience, a close economic scrutiny of this variant must be left for the future.

Below, pasteurization is discussed within the limits of the conventional activated sewage plant with digestion. It should be made clear that the average behavior of a digestion tank is rather difficult to define. On the other hand, it would be misleading to deny that such a factor exists, because all theories and calculation methods for digestion tanks would be nullified. But realistically analyzed degradation in the course of digestion should not be based upon the optimum conditions provided by the laboratory, since no such results are obtainable in practice.

Data supplied by six German clarification works (3, 4) indicate that approximately 330 l gas are produced per kilogram organic matter supplied (OMS) if digestion proceeds for 10 days, and 380/kg OMS, in 20 days. The estimates of five Swiss works amount to values of 190 to 210 l/kg total solid matter for digestion periods of 30 to 50 days. Assuming that the organic matter constitutes 60%, the corresponding German values would amount to 195 – 225 l/kg, i.e., slightly better results, considering the shorter period of digestion. Fair and Moore have theoretically estimated that if digestion proceeds at a temperature of 30°C for 30 days, gas production should amount to 750 l/kg OMS; in practice, therefore, only

half this amount is obtained. The correlations should be further elucidated.

The heat balance requires the assumption of a presumable balance between the solid material and volume, and this, in turn, should be established on the basis of known values. We may proceed from the assumption that 110 g solids per inhabitant, (or per population equivalent per day (i.d.)) are discharged in the fresh sewage sludge. After deducting a loss of 6% solids carried away in the digestion water, and of 60% organic matter, as well as a 50% loss of the latter in the course of degradation during digestion, the solids in digested sludge may be equated as follows:

$$\text{Solids in digested sludge/inhabitant} = 110\,[(1 - 0.06) - 0.6 \cdot 0.5] = 70\ \text{gr/i.d.}$$

and the volume of gas

$$V_G = 210 \cdot 0.11 = 23\ \text{l/i.d.}$$

The gas volumes measured in connection with sludge digestion amount to 1 l/i.d. On the basis of the above calculation the following quantitative balance is obtained:

	Fresh sludge	Digested sludge	Digestion water	Gas
Solids g i.d.	110	70	7	33
Wet amount kg i.d.	2	1	~1	0.03
Solids content %	5.5	7	0.7	-
Gas production l/kg solids	210	330	-	-
Gas production l/kg = m³ t wet	11.5	23	-	-

As evident, the degree of thickening of the sludge, both fresh and digested, is of major economic importance. The above figures are based on the assumption that appropriate digestion was achieved in a large plant, without a special thickener, but with a secondary digestion tank.

Corresponding to an average of 66% methane, the lower caloric value of which was 8,600 cal/m³ STP, the lower caloric value of sewer gas estimated at 5,600 cal/m³ STP, taking into account 5% residual humidity. In literature (3) this value is given as 5,500 cal/m³ STP.

The gas evolution at 30°C, in the usual digestion tank, may be expected to attain 23 m³ STP/t of digested sludge, or 11.5 m³ STP/t of fresh sludge, which corresponds to 64,000 cal/t fresh sludge. This should supply the necessary heating for digestion tanks, buildings, and if possible also for the pasteurization tanks.

The caloric expenditure for heating the digestion tank comprises the heating of fresh sludge, the loss of heat in the first digestion tank, and also any fuel-return line. Further estimates are, therefore, based on summer and winter requirements; actually, only the former are important, since the vegetation period may be considered to last from 1 April till 1 October.

Of this period, the month of April can be considered critical, because the mean day-temperature may still be low (the monthly mean in the valleys, excepting southern Switzerland, is 8.5°C, the lowest day-mean about 1°C). If it is impossible to balance the heat for a longer period, or at least for 10 days, and this can be calculated in each case by means of the gasometer size , from the figures quoted above, then the temperature of the fresh sludge in April must be expected to be approximately 5°C. Plants not fully loaded can, of course, accumulate sludge reserves in the second digestion tank, for bridging over the energy gap.

3. Energy balance

The credit side of the energy balance, comprising digestion and pasteurization, shows the heat gained from the sewer gas, as well as the subordinate energy supplied mechanically by the pumps.

On the debit side, the largest items are the heating of fresh sludge to the temperature of the digestion tank, say 33°C, and subsequent heating of the digested sludge to 70°C, for pasteurization. In between, the temperature drops to 20°C in cold weather, and 25°C in warm weather, this drop being indispensable for adequate settling of the digested sludge. The second digestion tank is, accordingly, not insulated. In addition, the heat losses of the first digestion tank, as well as those of the pump house and boilers should be taken into account. The arrangement is evident from Figure 1.

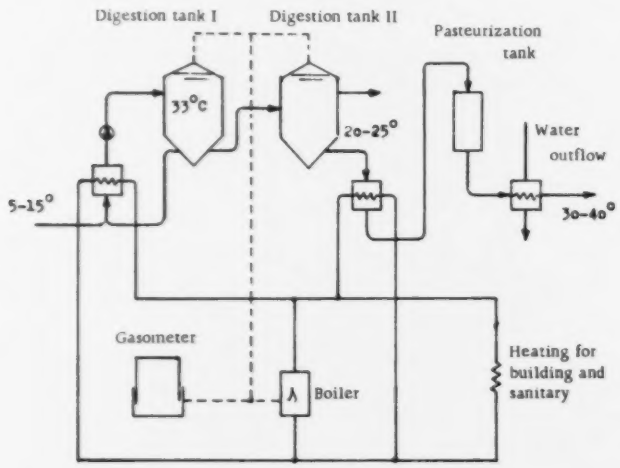

FIGURE 1. Sludge digestion and pasteurization with hermetic heating

To establish the balance, the items are referred to 1 ton fresh sludge. In appropriate conditions of digestion one ton fresh sludge is reduced to 0.5 t digested sludge. According to the data previously given, the gross heat evolved equals 64,000 cal.

Further, we shall consider two cases of climatic patterns:

1. The critical April period with a mean day temperature of + 3°C lasting for many days, a fresh-sludge temperature of + 5°C, and a digested-sludge temperature, after second digestion, of 20°C.
2. An average summer period with an outdoor temperature of +15°C, fresh sludge temp. +15° and digested-sludge temp. +25°C.

A rough calculation, which is justified in this case in view of the minute sum involved, shows that the temperatures of digestion tank I and the pump house can be maintained in small works with about 3%, in large works with about 2% of the heat required for the fresh-sludge heating (not valid for winter operation). For pasteurization, 2 to 3% of the sludge-digestion heating energy should be taken into account, according to system and arrangement.

The outflowing digestion-water with temperatures of 20 to 25°C hardly encourages heat recuperation, but the pasteurized digested sludge flowing out with a temperature of 70°C certainly does. The questions pertaining to heat recuperation will be discussed later. First, we shall examine the balance without heat recuperation, when heating is hermetic.

Fresh-sludge temperature	°C	April + 5°	Summer + 15°
Fresh-sludge quantity	t	1	1
Fresh-sludge heating	Δ t °C	28	18
Fresh-sludge heating	heat cal / t	28,000	18,000
Addition for heat losses		1,000	700
Digested-sludge quantity*	t	0,5	0,5
Digested-sludge heating	Δ t °C	50	45
Digested-sludge heating	heat cal / t*	25,000	22,000
Heat requirements, net	cal / t*	50,000	40,700
Stored-up energy of sewer gas	cal / t*	18,000	64,000
Boiler efficiency, estimated	%	78	78
Available heat	cal / t*	50,000	50,000

* Referred to 1 t fresh sludge.

It is evident that returns and expenditure are almost balanced in April without heat recuperation, provided no steam is mixed with the sludge.

The pasteurized sludge certainly cannot be loaded at 70°C and disposed at 50°C, because of the steam evolved and the inevitable foul odors. Here then the problem of suitable cooling arises. So far metal containers with air cooling were used. This method can be applied for small amounts. A heat-exchanger, or a spiral tube in the outlet would be more effective. Evaporative cooling cannot be considered because of the emanating odors.

4. Heat recuperation

Effective cooling of the pasteurized sludge can be obtained also through heat recuperation by various means. The simplest equipment for this purpose is a heat exchanger between the treated and untreated sludge. Its disadvantages consist in the danger of incrustation, which occurs also in similar heating systems, and the insignificant temperature gradient over considerable exchange areas. In principle, we have to deal here with calcareous deposits on the one hand, and with an accumulation of heat-degraded cell substance, on the other. Their joint occurrence may lead, according to local conditions (hard drinking water etc.), to the rapid formation of heat-inhibiting deposits. Addition of agents that may prevent calcareous deposits can hardly be avoided as soon as the wall surface of the heat exchanger exceeds 50°C.

Therefore, direct heating of the sludge with steam is preferred in most plants. However, it should be borne in mind that this method not only requires suitable conditioning of an adequate quantity of feed water, but also involves undesirable dilution of the digested sludge. By using low-pressure steam dilution of the digested sludge may attain 12%.

If direct heating is combined with heat recuperation, which is also performed without heat-exchange surfaces, then the heat transport should proceed in the form of condensation heat at reduced boiling temperature. This procedure is widely adopted in large works; in this case the installations are arranged as illustrated

in Figure 2: fresh sludge is heated to 70°C by means of a cascade C_1. Cascade C_2 is subjected to suitable low pressure, between 0.1 and 0.3 kg/cm², so that condensation sets in. The evolving vapors are compressed by a steam-jet blower, G, under the same pressure as in C_1, and thus part of the energy is recuperated in the form of vaporization heat. Access of air to the system is prevented by means of a vacuum pump, V. The cascade C_2 can be fixed so high as to allow the lifting of pasteurized sludge from C_1, and ensure, at the same time, the outflow of the cooled sludge by the gradient $h = 1 - p_e$.

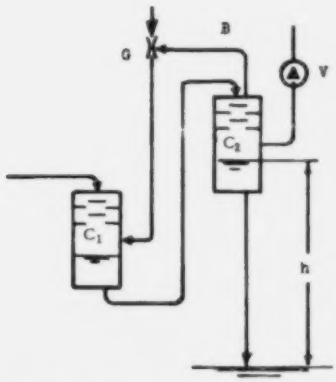

FIGURE 2. Pasteurization with heat recuperation

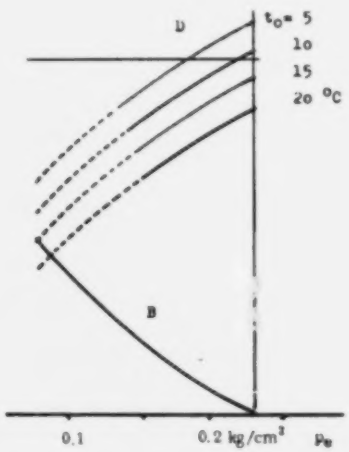

FIGURE 3. Quantities of heating steam and vapors

Figure 3 shows the diminishing requirements of heating steam, D, with progressive heat recuperation expressed by the amount of returned vapors, B, both in % of the amount of sludge passed through. The amount of heating steam, D, depends also upon the initial temperature of the sludge t_o. In view of the heat losses by radiation and through air removal, the final temperature of the pasteurized sludge lies between 40 and 65°C. The arrangement shown in Figure 2, with a return stage and a steam-jet blower, allows, on account of the low efficiency of the latter, only a modest recuperation of heat within the solid lines of D. In order to use the area lying to the left of it, multistage return lines should be chosen, in conjunction with other compression procedures.

Pasteurization may be performed in a continuous process, or in individual batches. The arrangement illustrated may be replaced by a special reactor instead of C_1, while the duration of treatment (20 minutes) and temperature (70°C) are retained.

Considering the arrangement described, the following balance can be established for 1 t fresh sludge, with or without digestion, for the critical April period with the fresh sludge at 5°C, as well as for the average summer period with a temperature of 15°C; all heat quantities are referred to 1,000 cal/t.

Balance with heat recuperation and direct heating for 1 t fresh sludge in 1,000 cal/t, for the month of April and for the summer period

Heat recuperation		Fresh sludge				Digested sludge			
		without		with		without		with	
Temp. of fresh sludge	°C	+5	+15	+5	+15	+5	+15	+5	+15
Temp. of digested sludge	°C	-	-	-	-	+20	+25	+20	+25
Heating and maintenance of temp. in digestion tank (1)		-	-	-	-	29	19	29	19
Heating-up span to 70°C		65	55	65	55	50	45	50	45
Quantity	t	1	1	1	1	0,5	0,5	0,5	0,5
Heat per t eff. (1)		67	57	58	50	52	47	44	40
Heat per t fresh sludge		67	57	58	50	26	23	22	20
Final temperature	°C	70	70	54	54	70	70	54	54
Netto heat demand		67	57	58	50	55	42	51	39
Heating steam demand (2) for:									
Digestion tank	kg/t	-	-	-	-	45	30	45	30
Pasteurization	kg/t	104	89	90	78	40	36	34	31
buildings and sanitary (3)	kg/t	8	8	8	8	4	4	4	4
Total amount of steam	kg/t	112	97	98	86	89	70	83	65
Heat in sewer gas		-	-	-	-	64	64	64	64
Amount of steam from sewer gas (4)	kg/t	-	-	-	-	80	80	80	80
Steam shortage	kg/t	112	97	98	86	9	-	3	-
Fuel oil requirements	kg/t	9,1	7,9	8,0	7,0	0,7	-	0,2	-
Final quantity of sludge	t	1,112	1,097	1,098	1,086	0,589	0,570	0,583	0,565

(1) With 3% loss for digestion, 10% for pasteurization with recuperation.
(2) At 3 kg/cm^2.
(3) Taking into account the heat losses during digestion and pasteurization.
(4) Boiler efficiency 78%, feedwater temperature 15°C.

The average load during the vegetation period is most important for the costing of pasteurization. In this case, the values to be taken into account will be somewhat higher in the central regions of the country than those indicated in columns 1, 3, 5, and 7; as a safety margin, an adequate additional increase is advisable.

As an example let us calculate the costs of a sewage plant for 10,000 inhabitants and sludge-population equivalents. The amount of solid matter (SM) in fresh sludge, at 110 g/inhabitant-day (i.d.), equals 1.1 ton/day. The amount of fresh sludge at 5.5% SM equals 20 ton/day. The variants without digestion may account for 182 days per year, at a mean temperature of 15°C, and those with digestion, for 10 days at 5°C.

Heat recuperation		Without digestion		With digestion	
		without	with	without	with
Fuel-oil demand at 15°C	kg/t	7.9	7.0	0	0
" " " per day	kg/t	158	140	0	0
" " " in 182 days	kg	29,000	25,000	0	0
" " " at 5°C	kg/t	-	-	0,7	0,2
" " " in 10 days	kg	-	-	70	20
Maximum demand of heat per day					
for digestion in summer*	kcal/d	-	-	0,58	0,58
for pasteurization	kcal/d	1,34**	1,16	0,52	0,44
Digestion in winter		-	-	0,64	0,64

* At + 5°C.
** Maximum values are underlined.

The fuel-oil costs can be estimated from the data given in the table. The mode of operation should be established before the heating system is installed. In order to prevent unnecessary peaks, heating for digestion of the fresh sludge should be separated from pasteurization as early as possible, but the daily energies as indicated in the table must be supplied.

In order to keep personnel costs down the operations described should be performed, as far as possible, during a single shift. In the case of heating before digestion, loading of the cold fresh sludge in digestion tank I with subsequent heating should be separated from the preheating of the entire daily amount, in order to avoid temperature fluctuations in the digestion tank. Temperature fluctuation is particularly marked when loading times are short, because the temperature of the mixture (in view of the proportion of the quantities in the digestion tank) approaches the temperature of the fresh sludge, i.e., it is too low for the thermophilic strains.

On the other hand, there is a definite lower limit to the delivery by the fresh-sludge pump; in the example given above it corresponds to a filling time of 2 hours. If the daily amount is preheated in another container (the pasteurization tank may be used for this purpose under certain circumstances), then the pumping can be effected in a considerably shorter time, and the heating extended over a longer period.

In works with a continuous processing system heating for pasteurization proceeds during the passage of the inflowing sludge. If the operation is not continuous heating can be carried out by a circulation circuit through the reactor; in this case the time of heating is limited only by the available daily working hours and the number of loads. In the Table the required heating output for the aforementioned variants is calculated on the basis of justifiable heating times. At the same time, allowance is made for increase of the daily throughput taking into account the loading of the digestion tank six days per week, and pasteurization five days per week.

Heat recuperation		Without digestion		With digestion	
		without	with	without	with
Heating time for digestion	h/day	-	-	2	2
Number of loads for pasteurization		2	2	1	1
Corresponding time for heating	h/day	4	4	2	2
Heat demand as calculated above for:					
Digestion $\frac{7}{6}$	kcal/day	-	-	0,75	0,75
Pasteurization $\frac{7}{5}$	kcal/day	1,88	1,62	0,73	0,61
Required heating output	cal/h	470,000	400,000	380,000	380,000
Final quantity of sludge in a 5-day week, in summer	ton/day	30 7	30,6	16	15,8

All these figures are based on the assumption that operation will run smoothly. In this connection, it must be mentioned that in regard to pasteurization we are still inexperienced. Therefore, adequate allowance should be made for reserve capacity in order to compensate breakdowns. In the case of plants with digestion it should be borne in mind that consistent planning of the digestion in relation to the loading of the digestion tank, maintenance of temperature (no cooling shocks), circulation, digestion time, and decantation of digestion water, as well as elimination of toxic substances and careful checking are the prerequisites without which the calculated degradation of solid matter and the concomitant amounts of gas cannot be achieved.

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PRINCIPLES OF COST-SAVING IN THE USE OF GARBAGE TRUCKS

By Dipl. Ing. Karl Perl, Thalwil

Selection of the site is the first task to be dealt with when installation of a refuse-disposal plant is contemplated; it involves extensive preliminary investigations. First, collection and transportation of the refuse to the disposal plant should be considered. A site should be selected that would involve a minimum of expenditure for these operations. In this connection, certain generally applicable principles can be derived from the recently published equations by F. C. Wüthrich (1).

For costs of collection and transport, i. e., the cost involved in driving the empty truck from the disposal plant to the center of the collection area, collection of the refuse in the area, the return of the loaded truck to the plant, and unloading, F. C. Wüthrich has established the following equation, assuming that the loaders travel both ways:

$$K = \left(p^{-\frac{3}{4}} + \frac{0.2 + 0.3\sqrt{D}}{L}\right) \left(6.4\sqrt{L} + \frac{(p+1)}{2{,}200}\, i\right) \ldots \text{Fr/t}$$

where:

i = yearly cost for one man in Fr/a
p = number of loaders in a team, without driver
D = distance from plant to center of collecting area in km
L = load capacity of truck in t.

The equation was established on the following assumptions:

1) The purchase price of a garbage truck can be expressed in Fr, by the equation $A_w \sim 46{,}000\ \sqrt{L}$.
2) The cost per hour of a garbage truck can be determined by the equation $W\ K_h = 6.4\ \sqrt{L}$
3) The operation time amounts to 2,200 hours a year.
4) The collection output of a man can be expressed in t/h by the equation $1 = p^{-\frac{1}{4}}$
5) The transportation speed of the truck in km/hr corresponds to the equation $v = 7\sqrt{D}$

The costs of collection and transport in Fr/t refuse were calculated on the basis of these premises for trucks with a load capacity of 3, 6, 8, 10, 15 and 20 tons; the loading personnel was assumed to vary in numbers.

Figure 1 shows, for example, the costs of collection and transport calculated on this basis in Fr/t refuse for one truck with a load capacity of 10 t, and for distances of 0 – 50 km, each curve being marked with the corresponding number of loaders (2 to 6).

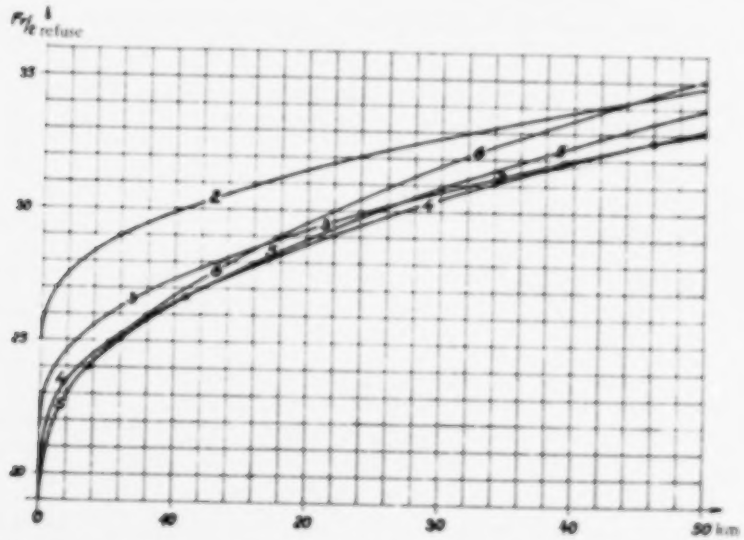

FIGURE 1. Costs of collection and transport in Fr/t refuse, for trucks with a load capacity of 10 t, and loading teams of 2 to 6 loaders, correlated to distances of up to 50 km

In Table 1 the number of loaders required, in relation to distance at the minimum possible cost of collection and transport, is summarized for a truck with a load capacity of 10 t.

TABLE 1. Number of loaders without driver required for a 10-t truck at minimum costs of collection and transport

Distance in km	Number of loaders
0 – 0.8	7
0.8 – 3.1	6
3.1 – 12	5
12 – 46	4
over 46	3

Similar studies have been carried out for trucks with a load capacity of 3, 6, 8, 15 and 20 tons. Since all the results are similar, it may be deduced in general that

for the purpose of minimum costs of collection and transport the number of loaders employed must be reduced with increasing distance.

The lower outline of the set of curves in Figure 1 represents the curve of the minimum possible costs of collection and transport for a refuse truck with a 10-t load capacity and transportation distances of 0 to 50 km.

Figure 2 shows such enveloping curves for refuse trucks of 3, 6, 8, 10, 15 and 20-t-load capacity, representing the minimum costs of collection and transport for distances up to 50 km. Each curve is marked with L in tons, according to the load capacity of the respective truck. The number of loaders (without driver) that should be employed at minimum costs for distances that can be derived from the figure, is marked on the curves by p (= 2 to max. 9).

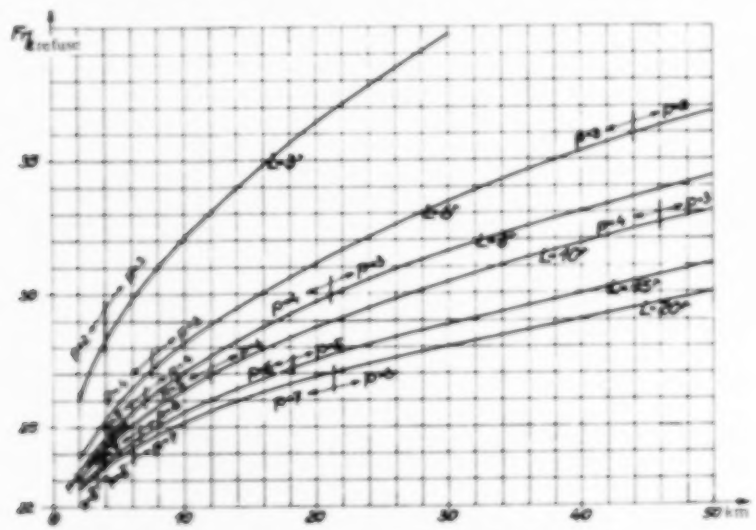

FIGURE 2. Minimum costs of collection and transport in Fr/t refuse for trucks with load capacity L = 3 to 20 t, and distances up to 50 km. On the curves the distances are defined over which a certain number of loaders p are to be employed

It is evident from the curves that the costs of collection and transport decrease as the load capacity of the trucks increases. But it is also evident that the cost reduction in relation to the increasing load capacity of the truck is not unlimited. Thus, the replacement of a 10-ton truck by a 20-ton truck at a distance of 2 km constitutes a saving of only 1.5%, whereas over a distance of 50 km the saving may amount to 9%. In general, therefore, collection and transport costs will be considerably increased by using a truck with a load capacity under 6 tons, but the use of vehicles with a load capacity exceeding 15 tons is likely to result only in theoretical savings, even over great distances. For short distances (see Figure 3) the curves are so closely packed that the theoretical savings can hardly be obtained in practice, and the size of vehicles to be chosen will more likely be determined by local conditions.

The costs involved in the trip of the empty trucks with load capacities L = 6 t and L = 15 t from the disposal plant to the center of the collection area, for the collection of refuse in the area, the trip back to the plant fully loaded and delivery

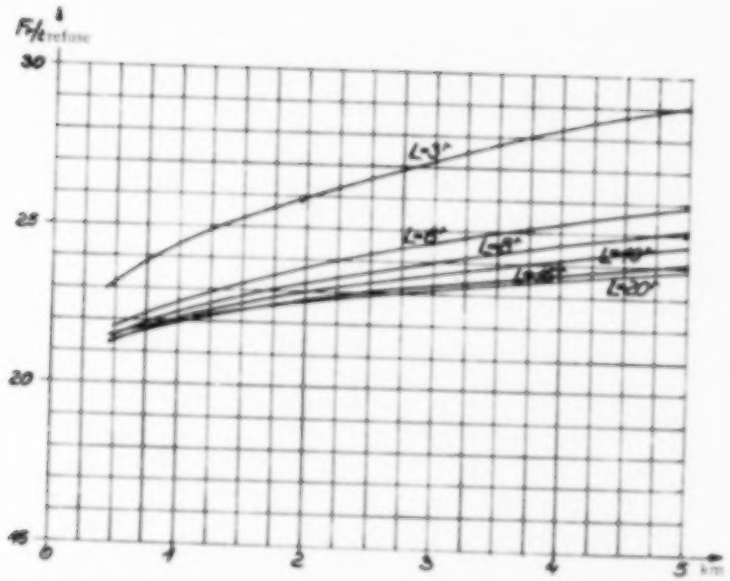

FIGURE 3. Minimum costs of collection and transport in Fr/t refuse for distances up to 5 km and vehicles with a load capacity L 3 to 20 t

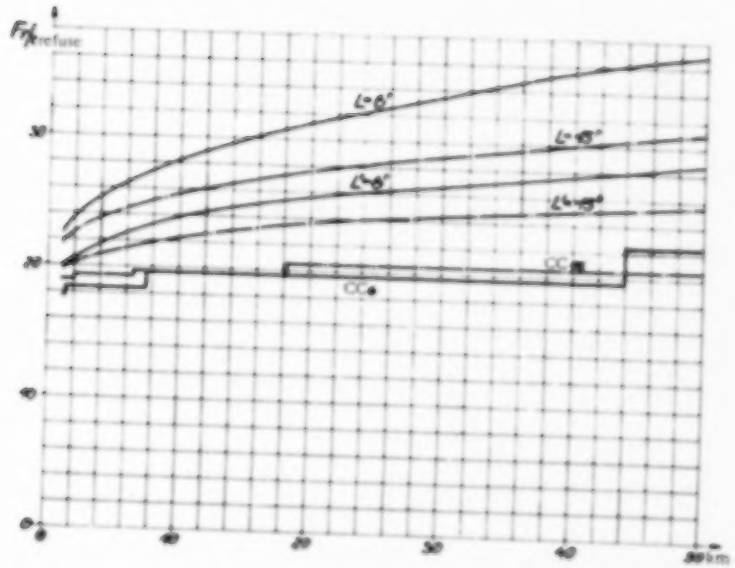

FIGURE 4. Comparative costs of collection and transport with vehicles of L= 6 or 15 t load capacity with accompanying loaders, and L' without loaders, correlated to distances up to 50 km, and the corresponding collection costs (CC)

there, are plotted in Figure 4, for distances up to 50 km. As before, it is assumed that the loaders make the trip both ways. The costs of collection CC are plotted in Figure 3 for both types of vehicles. It is evident that collection costs make up the greater part of the total costs. This proportion could be changed by using larger bins which, however, is not always possible. Another way of saving would be to exclude the loaders from both vehicles. The total costs in this case are shown by the curves L' = 6 and L' = 15. More than 10% of the costs can be saved over distances of only 2 km. Over greater distances, up to 20% could be saved, according to this investigation.

The minimum costs of collection and transport of refuse (in tons) during a 9-hour working day, with vehicles of L = 3 to 20 t, in relation to distance, in km, are shown in Figure 5, where p is the number of loaders to be assigned to the various distances, all previous assumptions remaining the same.

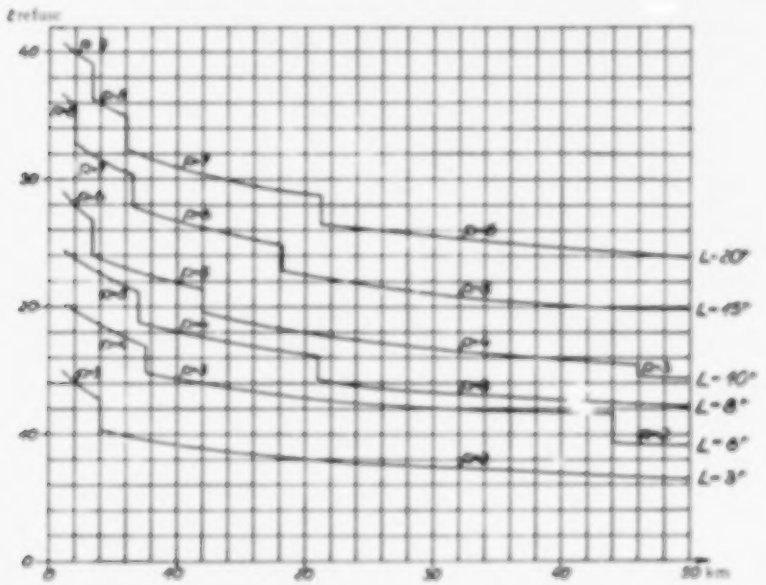

FIGURE 5. Minimum costs of collection and transport, with trucks of L = 3 to 20 t load capacity, in a 9-hour working day, in relation to distances, in km.
p = the number of loaders required (without driver)

This theoretical investigation is based on several premises which although expressed with the highest mathematical accuracy, do not always coincide with the actual findings; nevertheless, it may serve its purpose in offering certain generally valid principles for lowering the costs of refuse transport.

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OXIDATION-REDUCTION POTENTIAL AND THE HYGIENIC STATE OF COMPOST FROM URBAN REFUSE

By F. Möller, Institute for Hygiene, Potsdam
(Director: Chief Medical Councillor Dr. F. Köhler)

Knoll (1961), Strauch (1964) and Bürger (1965) have suggested the introduction of certain requirements in order to ensure the production of hygienically safe composts. If certain decontamination measures were taken in the course of processing, the final product could be considered free of pathogenic agents, and its use in agriculture and gardening recommended.

In the course of routine checks of composting sites in small towns and communities it was established that, unlike composting plants, these establishments were not always in a position to comply with the requirements, be it for want of adequate equipment for processing the refuse, or because of the frequent changes in the quantity and quality of the materials received. Hence the question arose whether composts produced in conditions which do not comply with the decontamination requirements must, in principle, be rated hygienically unsafe. The use of such composts in vegetable fields, or in plots with fruit cultures close to the soil surface could not be allowed, and therefore disposal plans of many such plants would be noticeably disrupted. For the sake of continuity of the reclamation process, which of late ends with the transfer of the compost direct to the buyer, we have engaged in the examination of the hygienic state of the final product. Sanitary controls of the final product of urban-refuse composts are extremely problematic, at least as a routine procedure, and have aroused opposition from various quarters (Moller, 1967). However, judging by our experience, it is not impossible to determine the hygienic state of the final compost, provided examination is made of certain reliable decontamination-indicators, apart from the demonstration of pathogenic agencies. The analytical procedure adopted will be described in detail, shortly. Here, the determination of the oxidation-reduction potential is dealt with in detail, since this procedure can be adopted in general production control.

Method

The oxidation-reduction potentials were determined according to the technique (Figure 1) of Mayer and Parrakova (1964). The measuring electrode consists of a platinum-coated glass rod (Figure 2, a). The reference electrode used is an ordinary commercial calomel electrode, sealed by a graphite rod, in order to prevent entrance of extraneous matter and avoid diffusion in the substrate of the potassium-chloride solution (Figure 2, b). Both electrodes are directly introduced in the substrate: 5-cm deep in the cover zone of the pile, and in the center of the pile (the core). The oxidation-reduction potential is ascertained (contrary to the suggestion of the afore-mentioned authors) with a battery-fed, high-resistance pH meter (hand-pH-meter MV 12 by the firm Clamann and Grahnert, Dresden, Figure 3).

With this procedure no changes of improperly buffered oxidation-reduction potentials are possible, nor removal of oxygen by an inert gas during operation (Flaig, Scharrer and Judel, 1955; Hankus, 1965; Mayer and Parrakova, 1964; Scott and Evans, 1955). The potential is read after three-minute tests, even if not stabilized within this time, as happened in our determinations.

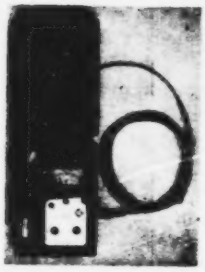

FIGURE 1. Instrument for electrometric determination of oxidation-reduction potentials, after Mayer and Parrakova (1964)

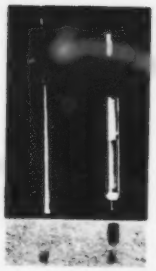

FIGURE 2. Electrodes: a = platinum electrode (platinum-coated glass rod); b = calomel electrode (graphite sealed) with locking cap to prevent drying up in transport

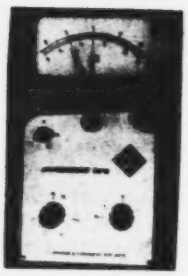

FIGURE 3. Measuring instrument (battery-fed, high-resistance, hand operated pH-meter MV 12)

The subsequent change amounted to < 5% of the 3-minute test value and could be ignored. In this connection, we should recall that in principle Hankus (1955) considered valid only the initial values of the "apparent redoxpotential" that result from the reversible system. According to her, subsequent shifts of the potential are not reproducible. Conversion of the Eh values (mV) to rH was abandoned since a direct comparison of the substrates of different piles or plants was not intended. The reaction of the composts examined was relatively uniformly neutral, notwithstanding the great variety of the raw material, and the different times of piling. For reasons explained by Flaig, Scharrer and Judel (1955) we recommend, for comparative studies, correction of the values obtained to the mean pH = 7 (E_7-values), instead of conversion to rH.

Since the values measured in the pile were, as expected in this heterogeneous substrate, widely scattered, ten parallel measurements were performed in each zone in order to obtain a mean value. The oxidation-reduction potentials of the core and cover zones, separately determined, were compared. The progress of fermentation in the pile is most clearly revealed by this comparison (compare Tepe, Leidenfrost and Darlowski, 1966). The degree of ripeness could also be determined, irrespective of the nature of the raw material.

Details relative to the technique of electrometric determination of the oxidation-reduction potential, such as completion and regeneration of the platinum electrode, preparation of the calomel electrode, calibrating the instrument, calculation of readings, etc., are found in the publications by Mayer and Parrakova (1964), and by Mayer and Hluchan (1962).

For the detection of salmonellas and coliforms the method used was the same as for the analysis of sewage-treated soils (Krannich and Möller, in press; Möller and Krannich, in press). In accordance with Knoll (1961)a and Strauch (1964), we required that the decontamination temperature in the center of the pile be maintained at > 55°C for at least 14 days after piling, as well as after turning.

Results

The results obtained in the analyses of eight composting plants in the Potsdam district are summarized in Tables 1 and 2. Routine control of the decontamination temperature is carried out only in the composting place W. The results obtained

in the analyses of the hygienic state of the MK-compost produced there were used as standards for comparison. All analyzed composts had been declared marketable by the producers.

As evident from Table 1, pathogenic salmonellas or coliforms appeared only occasionally, in negligible numbers (< 10 germs/g) when the oxidation-reduction potential was equalized between the cover and core of the compost pile. All composts were defined as ripe on the basis of criteria which shall not be discussed here. The oxidation-reduction potential in the core of the pile was found in an exceptional case 42 mV below that of the cover zone (S 1), and in six of the ten piles tabulated, above that of the outer layer.

The data summarized in Table 2 refer to compost piles which, according to our criteria, were not ripe, or in which digestion proceeds sluggishly owing to deficient aeration. The oxidation-reduction potential in the core zone was always > 50 mV lower than that of the outer layer. The required temperatures for decontamination were maintained in the W-composting plant and, as expected, no pathogens of the intestinal tract were detected in the final product. Therefore, although the degree of ripeness of these composts was found to be insufficient, according to the oxidation-reduction determinations, no objections were raised against these composts from the hygienic point of view. In pile B 73, in which the thermal decontamination conditions were not complied with, determination of the oxidation-reduction potential clearly established the unsatisfactory course of fermentation and insufficient degree of ripeness. The suspicion that purification of the sewage sludge could not be achieved in these conditions was confirmed by the bacteriological findings.

TABLE 1. Oxidation-reduction potential and hygienic state of ripe urban-refuse compost
F = fecal matter, K = digested sewage sludge, M = household refuse, N = Niedermoor turf, S = street sweepings, SK = pig excreta
Salmonellas : qualitative detection, average of five parallel tests
Coliforms : qualitative detection, quantitatively negligible (< 10 germs/g), average of five parallel tests
Oxid.-red. potential: average of ten parallel tests

Compost piles	Raw material	Duration of fermentation in days	Salmonella core	Salmonella cover	Coliforms core	Coliforms cover	Oxid-red. Potential in mV core	Oxid-red. Potential in mV cover
W 10/12	MK	246	∅	∅	∅	∅	206	199
W 9/11	MK	218	∅	∅	∅	∅	190	194
W 37	MK	223	∅	∅	+	∅	303	214
F 1	MSk	689	∅	∅	∅	∅	305	275
B 9	M	396	∅	∅	∅	+	263	266
N 1	SSk	752	∅	∅	∅	+	281	254
K 5	SF	287	∅	∅	∅	+	314	278
S 1	MF	581	∅	∅	∅	∅	334	376
G 6	M	526	∅	∅	∅	∅	281	262
D 3	M	586	∅	∅	∅	∅	253	284

TABLE 2. Oxidation-reduction potential and hygienic state of urban-refuse composts before ripeness is attained. (Designation of raw materials and examinations performed as in Table 1)

Compost piles	Raw material	Duration of fermentation in days	Salmonella core	Salmonella cover	Coliforms core	Coliforms cover	Oxid-red. Potential in mV core	Oxid-red. Potential in mV cover
W 1/3	MK	108	∅	∅	∅	∅	50	166
W 2/4	MK	97	∅	∅	∅	∅	88	159
W 5/7	MK	130	∅	∅	∅	∅	116	176
W 6/8	MK	184	∅	∅	∅	∅	140	204
B 73	KN	80	+	+	10^3	10^4	-200	184

Discussion

Mayer and Parrakova (1964) evaluate the oxidation-reduction potential as a partial indicator in the hygienic analysis of the soil. According to Andreasen (1952), Flaig, Scharrer and Judel (1955), Mayer and Parrakova (1964), Möller (1967)a, Shibuya, Saeki and Ryun (1939), organic impurities are certainly revealed in this way. Decomposable organic substances intensify microbial conversions in the contaminated layer leading to increased uptake of oxygen, and also to a fall in the oxidation-reduction potential (compare Hankus, 1965). Direct evolution of a potential from organic oxidation-reduction systems (including degradation products of the organic matter, metabolites of microorganisms, etc.) is controversial (Buchholz, 1961; Flaig, Scharrer and Judel, 1965; Hankus, 1965; Karbach, 1954). The oxidation-reduction potential rises again after mineralization of the decomposable organic substances. Factors that interfere with regular aeration of the substrate, as for example excessive moisture, disturb the dynamics of the oxidation-reduction relationships (compare Kauritschew and Andratzkaja, 1966; Ponomarewa and Bazilinskaja, 1966).

Therefore, it is our opinion that determination of the oxidation-reduction potential may be instrumental in evaluating the progress of digestion in compost piles whose content of decomposable organic matter decreases up to the stage of ripeness (Obrist, 1965, 1967). Tepe, Leidenfrost and Darlowski (1966) have recently drawn attention to the correlation of the degree of ripeness with the values of the oxidation-reduction potential of "soil solutions" (established with the aid of indicators).

In our investigation the results of the odor, fly and visual controls (Gotaas, 1956) of the quantitative determinations of carbon and nitrogen, the coefficient of anaerobiosis (Hirte and Heinrich, 1965), and the results of the recently adopted Chaetomium-test (Obrist, 1965) as criteria of the degree of ripeness, agree, in general, with the determinations of the oxidation reduction potential. The material of a compost pile may be defined as throughly fermented when the oxidation-reduction potential of the core zone lies < 50 mV below that of the outer layer. Soluble components of the oxidation-reduction system are, presumably, washed out from the outer layer by precipitation, so that on completion of fermentation the oxidation-reduction potential is disturbed in the layer proximal to the surface, and may drop below that of the core of the pile.

Numerous similar findings made us aware of the fact that the degree of fermentation of refuse composts is correlated with their hygienic state. Despite the repeated demonstrations of salmonellas and coliforms in large numbers in the raw material received (domestic waste, sludge, fecal matter), we were able to rate the marketable products as hygienically reliable, even without information about the thermal decontamination conditions, provided they were found ripe according to the oxidation-reduction potential. We agree with Knoll (1961)a that this can be attributed to the biological self-purification of the substrate. Similar to the processes encountered in the purification of sewage, extensive purification of the refuse may be expected after completion of the "first purification phase" (degradation of the organic substances accessible to microorganisms). In thermophilic fermentation annihilation of disease agencies is achieved even before attaining ripeness. In our opinion, if a compost producer cannot comply with the requirements of thermal-decontamination conditions, he should be allowed to deliver the

product only after the stage of ripeness is attained. Refuse dumped in anaerobic conditions in which pathogens can occasionally be detected even after completion of "composting", should not be sold for use in vegetable plots (B 73: so-called cucumber soil).

Since the degree of compost fermentation serves as indicator of the purity, and as a criterion of the marketing stage, or plant-tolerance, the electrometric determination of the oxidation-reduction potential should be adopted as part of the general production control. This method has the advantage of requiring only a moderate amount of work, eliminating extraneous factors and allowing direct testing on the spot. Compared with the techniques employed so far for this purpose, this is a remarkably quick method.

Studies are now in progress on model composts and plant composts in order to examine to what extent the values obtained by determination of oxidation-reduction potentials are comparable with the results obtained by other means of measuring the degree of fermentation.

Summary

In analyses of the hygienic state of urban refuse composts ripe composts have always been found to be free of pathogens of the intestinal tract, and only occasionally carrying a negligible number of coliforms. The degree of ripeness of the compost was established by determinations of the oxidation-reduction potentials. Balanced potentials between the core and cover of a pile indicated completed fermentation. When the degree of fermentation proved insufficient the oxidation-reduction potentials of the core zone were > 50 mV lower than those of the cover zone. The procedure is recommended for quick estimations in the control of production and hygiene in pile-composting plants.

Ing. J. Mayer, Bratislava, has supplied a prepared calomel electrode and contributed valuable advice for the performance of the tests.

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*COMPOSTING OF URBAN REFUSE**

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Experiments in the DANO-Plant of the Bad Kreuznach Soil Melioration Society

The purpose of every refuse treatment is to obtain a product of the smallest possible volume that can be harmlessly disposed. To this end selection of the procedure depends upon careful consideration of the problem from all aspects, taking into account all local and regional conditions and possibilities.

Composting is one of the refuse-disposal procedures. With its aid solid and liquid urban refuse – mainly domestic garbage and sewage from urban clarification plants – can be converted by biological oxidation into a hygienically harmless and esthetically acceptable form, considerably reduced in volume. Although composting solves only part of the problems involved in refuse disposal, it is now, as before, of considerable importance.

Increasing demands of an esthetic-hygienic nature, and economic considerations require that composting be widely mechanized ; at the same time it is aimed at furthering or speeding up the biological processes of conversion. The possibility of achieving this is offered by a recently introduced combined installation, which in addition to the equipment necessary for mechanical comminution and incineration, also possesses a rotating fermentation drum that can be artificially aerated.

The essential advantages offered by this fermentation drum may be summarized as follows:

a) The critical initial phase of composting takes place in a closed system that can be controlled, thus preventing offensive odors and vermin.

b) In the rotating fermentation drum the material, through constantly being turned over, is thoroughly mixed under extensive comminution.

c) The fermentation can be controlled so that the process is intensified or speeded up.

d) At the temperatures evolving in the fermentation drum (from 50° to 65°C) a mechanical and biological breakdown takes place of part of the material to be composted, and in addition a considerable amount of water is given off in the form of steam; if certain measures are taken (which shall be discussed later) decontamination of the product can be achieved.

e) It is known that different branches of agriculture require different compost properties. For field crops the breakdown of the organic matter in the compost should be as limited as possible, whereas for vegetable crops a well digested, stabilized product is required. Preliminary fermentation in the drum makes it possible for the compost manufacturer to supply a product suitable for various purposes. When the material has reached the state of hygienic safety, it may be immediately used for field crops, while for buyers requiring a riper product, the material can be further composted in piles.

Neat operation and smooth running of compost plants require, in addition to the appropriate technical equipment, also ample knowledge of the biological-chemical transformations and physical changes to which the material to be composted is subjected. On this point, unfortunately, there is still a great deal of confusion and some misconceptions, which led to mistakes and erroneous estimations in the past.

* See "Der Städtetag", No 7, 1967

The experiments described below were undertaken in order to examine the biological and hygienic effects of a quick-composting procedure based on a horizontally-rotating fermentation drum of the Dano-system. It was intended to find out to what extent quick decontamination by hot composting would comply with the maximum protection of the organic matter. The experiments were carried out over a period of several years at the Dano-plant of the Soil-melioration Society Bad Kreuznach.

The fermentation processes were determined by measurements of temperature and moisture and also by analyses of the oxygen content and carbon dioxide evolution, all of which provided to a certain extent the criteria for most of the biologically induced conversions. These determinations in the digestion drum were supplemented with analyses of the nutrient material and of the organic matter in the yield of fresh compost.

The hygienic analyses were carried out with pure cultures of human and animal pathogenic agents. These analyses were intended to establish to what extent the Dano-system complies with the basic requirements of hygiene, i.e., whether the procedure and product can be considered hygienically harmless.

All analyses were carried out with conventional methods, as well as with those specially developed for compost analysis. The following is a short summary of the most important results obtained, together with the conclusions and evaluation of the procedure.

Temperature

As a result of the biologically induced self-heating the temperature of the material in the normal course of fermentation rises in the first section of the drum to 45° – 55°C, and in the last third of the drum – the principal fermentation zone – to 65° – 70°C.

Measurements revealed a certain gradient from the core towards the wall of the drum, for which heat localization in the core and radiation to the outside may be responsible. The temperature gradient from the core to the periphery is, on the average, approximately 7° – 10°C. Hence, there seem to be various fermentation zones in the Dano-drum, i.e., fermentation proceeds with different intensities in different parts of the drum.

The evolution of heat was proved to be closely dependent upon the moisture content of the material, the supply of fresh air, and the filling height in the drum.

Moisture

In addition to a suitable composition, the optimum water content of the material is a decisive prerequisite for the decomposing activity of the microorganisms involved in fermentation. The water content of refuse fluctuates according to origin and season, the winter refuse containing less moisture than the summer refuse. In the conditions prevailing in Kreuznach the water content varies in the course of a year from about 20% to more than 50%. Therefore, when garbage and sewage sludge are composted together the addition of fluids should be adjusted according to local and seasonal conditions.

The limiting and optimum values obtained in the Kreuznach experiments are summarized in Table 1. Below the minimum limits listed the fresh compost usually lacks the desirable friable structure; it remains fibrous and strawlike and, moreover, may lead to formation of dust and to soilage. Above the given values

the temperature in the drum drops and at the same time big lumps (as large as cabbage heads) form in the drum, which beside depleting the compost, may lead to unpleasant odors emanating from the anaerobic foci thus formed.

Oxygen and carbon-dioxide content

A satisfactory course of the fermentation processes requires primarily the maintenance of aerobic conditions throughout the drum. The following survey shows the average values of O and CO_2 obtained in the fermenting material during the four seasons of the year, under constant air supply. As evident from Table 2, the presence of oxygen was established throughout the fermenting material. Further, it can be seen that the oxygen demand is highest in the last third of the drum, where fermentation is most intensive. Consequently, the maximum number of air-supply valves, which are fitted along the entire drum, must be opened in this section, in order to satisfy the increased demand.

The amounts of CO_2 found in the various sections of the drum are relatively small in comparison with those that may be recorded in nonaerated composting piles. This finding leads to the conclusion that the excess of fresh air blown into the drum not only ensures the oxygen supply for the fermenting material, but also carries off into the atmosphere ample amounts of CO_2 released in the process of biological degradation of the material.

Filling height

The height of the material in the drum was experimentally varied from 1.60 to 2.40 m. Well defined differences in temperature were recorded. Hence, by changing the filling height it is also possible to influence the course of fermentation.

The lower the filling height, the lower remained the temperatures. In Bad Kreuznach the optimum height was found to be around 2.20 m.

TABLE 1.

	Water content	
Summer months	minimum	30 – 35%
	optimum	35 – 40%
	maximum	50 – 55%
Winter months	minimum	25 – 30%
	optimum	30 – 35%
	maximum	40 – 45%

TABLE 2. O_2- and CO_2-amounts contained in the pores of the fermenting material in the Dano drum (in vol.%)

	Inlet		Middle		Outlet	
	O_2	CO_2	O_2	CO_2	O_2	CO_2
Test point* 1	4.1	11.4	3.4	10.0	1.8	14.3
Test point* 2	4.8	11.0	3.2	12.1	2.2	14.8
Test point* 3	8.6	7.1	5.2	8.1	2.6	10.4
Test point* 4	13.3	4.3	6.8	6.6	4.4	10.2
Test point* 5	17.1	0.8	12.8	3.6	6.2	8.6

* Position of test points at equal distances along the radius of the material. 1 = core. 5 = peripheral zone.

Sewage-sludge addition

The Dano-system was adopted in Bad Kreuznach mainly because several specialists thought it would be possible to process together population-equivalent quantities of fluid sewage sludge containing 90% water. However, this assumption could not be confirmed experimentally. Conditions in Bad Kreuznach allowed only approximately 10% of the fresh sludge, yielded in the mechanical-biological clarification plant, to be processed with the garbage, without converting the aerobic fermentation into anaerobic digestion.

Experimental sludge dewatering in drying beds, to 60 – 65% moisture would seem to indicate that composting of equivalent quantities of garbage and sewage sludge together is possible in the rotating drums.

Composition of the fresh compost

a) Content of organic substance

Analyses carried out in the course of five years of the so-called utilizable organic substance showed certain fluctuations during the year: about 15 to 19% in the winter period, and 20 to 27% in the summer season. The sharp differentiation that used to be made decades ago between winter and summer garbage is, however, no longer justified now. The average content of organic substance increased by a few percent during the five years.

The results obtained reveal that the content of utilizable organic substance in the fresh compost is quite considerable and that losses should be effectively prevented by adequate measures during fermentation.

b) Content of nutrient material

Although in view of the present state of knowledge about the preferable components of compost the priority of pure nutrient material cannot be assessed, information about the content of nutrient material is necessary if unreasonable dosage of compost and of the supplementary mineral fertilizer is to be avoided. A general picture of the content of principal nutrients in general, and their changes during the five years of testing may be gained from the mean values for the years 1958/1959 in comparison with those of 1963, as summarized in Table 3.

The significant drop in the total fraction of mineral material (ash) as well as in calcium content is worth noting, since these were always suspected of having a negative effect on compost-treated soils. The increase in the principal nutrients, N-P-K, may be considered equally advantageous.

TABLE 3. Content of principal nutrients in fresh compost, yearly mean in % of dry substance

	Ash	Total-N	P_2O_5	K_2O	CaO	MgO	pH
1958/59	63,27	0,64	0,47	0,67	6,83	0,86	7,41
1963	53,91	0,69	0,58	1,02	4,41	1,06	7,05

Hygienic tests

The hygienic requirements are based on the established fact that solid and fluid refuse of human habitations carry pathogenic agents. This is especially true of sewage sludge, in which the agencies of disease of man and animals are concentrated. These pathogens are not annihilated in the course of alkaline anaerobic digestion of the sewage sludge in unheated, or mesophilic digestion

tanks. Therefore, pathogenic microorganisms may be expected in any sludge originating from digestion tanks.

Since considerable amounts of sewage sludge are added to the refuse in the Dano-stabilizer, the question arose whether the pathogens were annihilated in the preliminary fermentation in the biostabilizer. For this purpose testing of the final product alone is not sufficient. If, by chance, the initial material was germ-free, no germs would be revealed in the end product. A satisfactory composting procedure from the hygienic standpoint would be one that allows tracing the fate of disease agencies throughout the process of fermentation. For this purpose, well known and clearly determinable organisms would have to be introduced in the raw material and their behavior in the biostabilizer examined.

The test organisms used were salmonellas known to differ in their resistance to heat (the bacilli responsible for typhoid, para-typhoid and enteritis), and also B. anthracis known to cause anthrax. The latter was chosen because it belongs to spore formers, i.e., the most resistant bacteria. If annihilation of this agent is successful, it may be concluded that less resistant organisms will also be made harmless.

The test organisms, packed in perlon bags, were applied to the homogenized refuse of the respective day. Each bag contained, in addition, an ampoule filled with the same organism, so that only the temperature could affect the content of the ampoule. The perlon bags were placed in perforated metal balls, and the latter hung on steel cables and anchored at six different points in the biostabilizer. According to the special requirements of the test, these balls were shifted from time to time three meters further, thus allowing them to pass through all the phases of the fermentation process. The temperatures of the fermenting material at the sites on which the bags were hung were automatically recorded throughout the test. At the end of the passage through the drum, viability tests of the organisms in the perlon bags were carried out in the laboratory.

The extent of annihilation of the above-mentioned microorganisms in the preliminary fermentation in the biostabilizer was established in ten experimental series with more than 350 single tests. From the processed data of all the results obtained it may be concluded that: normally sensitive salmonellas become harmless within prefermentation of three to five days. Less sensitive types (S. cairo) are inactivated only after five to seven days. The anthrax bacilli were in most cases still alive after seven days, but when subsequently subjected to further fermentation in compost piles these organisms perished within four days in the pile. The anthrax bacilli were, apparently, damaged by prefermentation in the biostabilizer, since they were more readily destroyed in the pile than germs that had not been exposed to prefermentation prior to composting in the pile.

Evaluation of the Dano-procedure

On the basis of tests carried out over a period of several years it has been established that the Dano-procedure, operating on the principle of aerated rotating drums, offers, from the biological and hygienic standpoints, a suitable solution to the large-scale processing of domestic waste and sewage sludge.

The continuous mixing movement combined with moistening and aeration of the material in the rotating drums provide suitable conditions for biological fermentation processes. By constant transposition of the contents continuous rotation of the drum effects a gradual comminution of the material, which is rather bulky in the beginning, and thus achieves an enlarged surface of the organic material to be attacked by the microorganisms. Far-reaching homogenization of the initially heterogeneous material takes place parallelly.

Beside the possibility of adding to the garbage certain amounts of liquid sewage sludge (containing about 90% water), joint processing of population-equivalent quantities of sewage sludge is also feasible provided the sewage is adequately dewatered beforehand, so that upon its addition the optimum moisture range of the mixture will not exceed the upper limit.

If the moisture and filling height of the material are maintained within the ranges indicated above, prefermentation in the rotating drum and subsequent fermentation in compost piles – if the need arises – will proceed in optimum conditions. The controlled, intensive, initial phase of fermentation in the drum proceeds with a pronounced evolution of heat.

Hygienic analyses have established that salmonellas are always inactivated in the biostabilizer within six to seven days. Anthrax bacilli are not reliably killed within this time, but if subsequently placed in a composting pile of prefermented material their inactivation was always achieved within four days. This secondary composting is advisable also for the annihilation of salmonellas because there are hardly any compost plants left at present that would guarantee a seven-day run through the drums.

The value of controlled prefermentation in rotating drums for the composting of garbage and sewage sludge lies in the rather short time required for the transformation of these unesthetic materials into a product that is hygienically safe, has a suitable structure, is still rich in organic matter and which according to the more recent concepts, can be directly and successfully used in various branches of agriculture.

ANNOUNCEMENTS

The IV International Conference of IRGRD on Disposal and Reclamation of Domestic and Industrial Solid Waste to be held in Basel, in 1969

We draw your attention to the IV International Conference of IRGRD which will take place on

2 – 7 June, 1969

on the premises of the Mustermesse, in Basel. Lectures and discussions will be held on 2 – 5 June, 1969, followed on 6 and 7 June by numerous, partly parallel, guided tours of the more recently established waste treatment plants in Switzerland. The IRGRD Conference is organized jontly with the Pro Aqua Fair and Convention, on the general theme: "Water and Sewage in Industry." The lectures of the Pro Aqua Convention will be held on 28 to 30 May, 1969. Inspections on 31 May, 1969. The fair will be open from 29 May to 4 June, 1969.

Development of the Dano System (continued)

In the IRGRD Information Bulletin No. 29 we explained that the present-day sweepings are very suitable for composting in general, and especially for processing with the Dano system, which is based on spontaneous grinding in horizontal rotating drums. While the material is thoroughly mixed and the volume considerably reduced, this kind of grinding also has the advantage of minimum wear and tear of the machines. The maintenance and repair costs of the Dano-system amount to SFr 0.50 – 1.5/ton. According to the size and load of the installation, the costs of current consumption range between 1 and 3, salaries between 2 and 6 and interest and amortization between SFr 5 and 15 per ton.

Taking into account that one ton of refuse produces only 0.6 t compost (compare IRGRD No. 31, page 201), it becomes clear that the production of compost can cover the expenses only under special conditions. These are: adequate size of the installation, demand for humus, and an organization for the distribution of the compost.

However, th. expenses need not necessarily be covered by compost sales. All other disposal methods involve considerable expenditure. Controlled tipping, whether limited to garbage and bulky waste or only to incineration residue, complies with the present requirements only if it is well protected from leaching, does not emanate offensive odors and smoke, nor produce dust, or encourage breeding of vermin, and if it is subsequently covered with humus and afforested. The provision of humus by means of compost is alreeady a gain for the national economy.

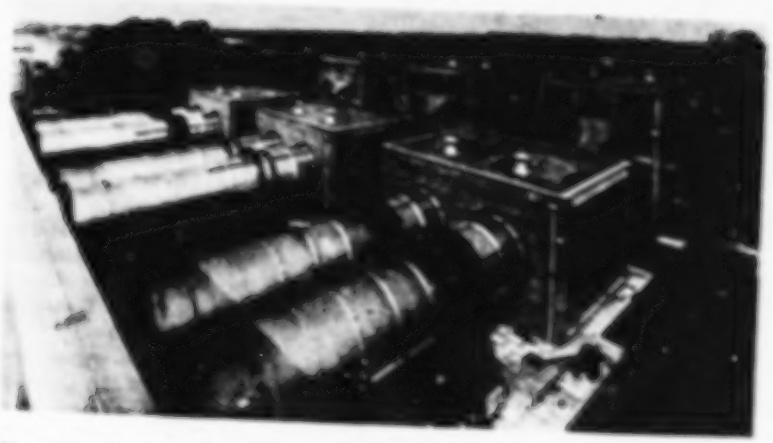
A new Dano installation, specially set up for controlled tipping, is operating in Aberdeen, Scotland (handling 300 t/day).

To the credit of composting with the Dano-biostabilizer should be added the costfree co-processing of sewage sludge. One third of the equivalent amount of normal digested sludge, or the entire amount of centrifuged or filtered material can be treated together with the garbage. The hygienic problems which arise particularly in the processing of sewage sludge were studied at the Edinburgh and Giessen universities, and results in favor of the Dano system recorded.

The value of the compost should be added to the economic advantages, and those of hygiene and sludge processing. Given the appropriate use, composting is one of the most sensible methods of disposal.

The compost is now richer in organic substance than before, while the nutrient material has not increased considerably. These new properties should be taken into account when evaluating the compost. Two types of compost are now available: fresh compost, which is relatively cheap, and ripe compost. On the average, 1,000 kg compost with 45% moisture contain:

	Fresh compost	Ripe compost
Decomposable organic substances	270 kg	130 kg
Nitrogen (N)	4 kg	6 kg
Calcar (CaO)	17 kg	22 kg
Magnesium (MgO)	5 kg	7 kg
Phosphorus (P_2O_5)	3 kg	5 kg
Potassium (K_2O)	2 kg	2 kg



The Dano-composting plant in Leicester, for 600 t/day. The sewage-sludge filters are installed directly above the composting cells, as a hall partly visible in the left corner.

The mineral components remain constant during ripening, but their percentages increase because they are referred to the decreasing amounts of solid matter.

Fresh compost has a slight indirect effect on nitrogen, frequently negative, i.e., part of the soil nitrogen is bound, and released only in subsequent years. One third of the nitrogen in the ripe compost is available in the first year, and in each subsequent year one third of the remaining nitrogen is released. In other words, the nitrogen is continuously absorbed but only at a slow pace. An ample supply of slowly available nitrogen is an asset for the plants, and its value exceeds that of soluble nitrogen. The calcium content of the compost is also set free at a low rate.

The value of the compost largely depends on dosage. The compost is most beneficial when applied in moderate doses (20 – 30 t/ha yearly), and supplemented with mineral fertilizers. With this method the nitrogen value of the ripe compost attains SFr 5 to 10 per ton, in addition to its humus value.

Many reports on experiments with compost in agriculture, in Holland, Belgium, Germany, Denmark and France, are available in the literature. The uses in special fields are mentioned because they classify the properties of the compost. In top-dressing for roses and tomatoes Danish gardeners report better results with compost than with turf and cattle dung. For the maintenance of golf courses compost has proved to be the best means. Slopes along highways and express motor roads have been covered with compost and planted.

In forest-tree nurseries the compost is particularly valuable for its property of retaining moisture and preventing crust formation.

The Dano system continues to be developed in the field of machinery and agricultural techniques.

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